

Unmanned Satellites on Postage Stamps: The A-train Satellite Constellation

authors Don Hillger SU 5200 and Garry Toth

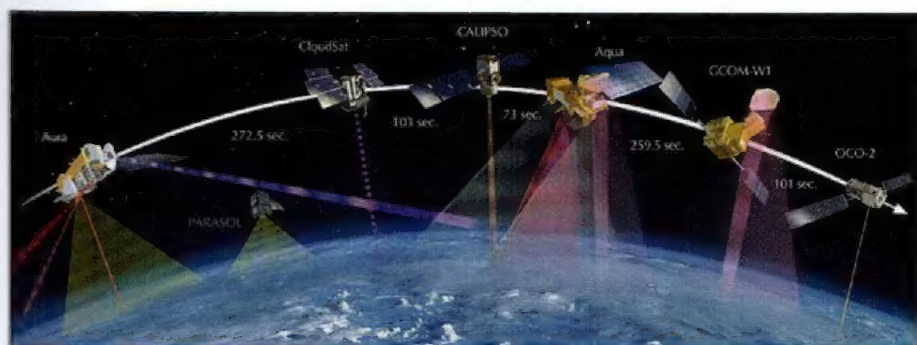
Authors' Note: The authors have decided to abandon further numbering of their un-manned satellite series of articles, having reached #50 with the last installment in this series. The slow pace of publishing has been far outstripped by the web pages and checklists that the authors have produced. Therefore, instead of continuing down the same path as before, we have decided to concentrate our publishing efforts on selected groups of satellites or satellite series. This will move us forward through our accumulated material more quickly and into areas we have worked on more recently. This was explained at the end of our last article (#50) and is repeated here for the benefit of readers who follow our un-manned satellite series.

A-train constellation satellites

This article features the satellites in the **A-train** constellation, or **Afternoon-train**, based on the

afternoon local equator-crossing time (1:30 pm) for all of these polar-orbiting satellites when part of the constellation. As many as seven satellites have been in the A-train, but never more than 6 satellites at any time. As of the writing of this article only four satellites remain. Some satellites have aged and moved out of the A-train to other orbits. Regardless, this article will cover all of the satellites which were at some point or are now part of the A-train.

The A-train contained the following five satellites from about 2006 to 2009: EOS-Aqua, EOS-Aura, PARASOL, CloudSat, and CALIPSO. All of these satellites have similar sun-synchronous nearly-circular orbits (705 km altitude and inclined 98.2° with respect to the equator) following one another in a pattern, like airplanes flying in formation, in the A-Train satellite constellation. The satellites cross the equator (northbound or ascending) within a few minutes



*The A-train constellation at its maximum contingent of 6 satellites
(A 7th satellite, PARASOL, is in a lower orbit)*

of each another at around 1:30 pm local time. Furthermore, due to their polar orbits, they likewise all cross the equator in the opposite direction (southbound or descending) on the opposite side of the Earth at 1:30 am local time. By combining the different sets of observations from this string of satellites, scientists are able to gain a better understanding of important parameters related Earth's weather and climate.

Below are some details on each of the satellites in the A-train constellation:

1) **EOS-Aqua (Earth Observing System)** was launched on 4 May 2002. Aqua was originally named EOS-PM for its afternoon (PM) local-time equator-crossing time. The EOS satellites are central to NASA's Mission to Planet Earth (MTPE) program. Aqua is a follow-on to EOS-Terra launched in 1999, which has a morning (AM) local-time equator-crossing time. Aqua in turn was followed by EOS-Aura (described below). The Terra and Aqua names stand for earth and water, but both satellites take wide-swath images and measurements covering the entire Earth every 12

hours. Although EOS-Terra is not part of the A-train, postal items depicting Terra are grouped in the authors' checklist with Aqua and Aura.

Various instruments on EOS-Aqua take multi-spectral measurements at numerous wavelengths in visible, infrared, and microwave wavelengths. In addition, hyper-spectral measurements are collected at nearly 2400 different wavelengths across the near-infrared and infrared parts of the spectrum. The satellite dimensions are 2.7 m x 2.5 m x 6.5 m (stowed) and 4.8 m x 16.7 m x 8.1 m (deployed) with a total mass of 2934 kg at launch; therefore, it is quite a large satellite! At one point EOS-Aqua was the lead satellite in the A-train constellation, but the OCO-1 satellite (discussed later) was to take the lead position before its failed launch in 2008. One of the larger and more detailed depictions of EOS-Aqua on a postage stamp (from Maldives Islands) is shown here (one of four different stamps in a miniature sheet). Readers are encouraged to check the authors' website for a number of other postage stamps showing Aqua.

2) **EOS-Aura**, a satellite with an atmospheric chemistry observing mission, was launched on 15 July 2004. (EOS-Aura should not be confused with the French D-series satellite (D-2B/Aura) which goes by the same name). Aura was designed to monitor ozone and related molecules in the stratosphere (upper parts of the atmosphere) and troposphere (lower atmosphere). Aura is a large satellite like Aqua, and is the last/trailing



Maldives Islands Scott 2895c Michel 4542 (2006)

satellite in the A-train constellation. A large depiction of EOS-Aura is found on another stamp in the same miniature sheet from Maldives Islands which contained a stamp showing Aqua. Other postal items can be found online.



Maldives Islands Scott 2895d

Michel 4543 (2006)

3) PARASOL (Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from a Lidar) is a French (CNES) mini-satellite launched on 18 December 2004. PARASOL instrumentation is specifically designed to measure the direction and polarization of light reflected from areas of land observed by the lidar carried by CALIPSO (information to follow). PARASOL was placed in the middle of the A-train constellation to follow CALIPSO. However, PARASOL was moved out of the A-train in December 2009 to another (lower) orbit, but not into the C-train that was formed by other satellites also moved out of the A-train. No postal items are known to separately show PARASOL, but it can be found on two postal items that have images of the A-train, both of which will be shown later.

4) CloudSat (CLOUD SATellite) was launched along with CALIPSO (discussed in the next paragraph) on 28 April 2006. CloudSat carries a single Cloud Profiling Radar (CPR) operating at 94 GHz (3.2 mm wavelength). Unlike the passive instrumentation on most satellites, the active radar on CloudSat sends signal pulses, similar to those of most radars, but CloudSat's pulses are sent vertically down towards the surface and are reflected by clouds. The nadir-only measurements are used to probe cloud structure at a vertical resolution of 500 m and width resolution of 2 km. CloudSat is a small satellite with two equal and opposite solar panels. It was modeled after the QuickBird design and was built by Ball Aerospace in Boulder CO. CloudSat was for many years the second satellite in the A-train constellation until it was moved out of the A-train to another (lower) orbit in February 2018. It is now part of the C-train. (The C-Train [the CloudSat and CAPILSO train] flies 16.5 km below the A-Train and therefore follows a slightly different ground track, though it intersects the A-Train ground track about every 20 days allowing for regular simultaneity between A-Train and C-Train instrument observations.) A large and detailed depiction of CloudSat is found on a third stamp in the same miniature sheet from Maldives Islands which contained stamps showing Aqua and Aura. Other postal items with CloudSat are found online.



*Maldives (Maldivian Islands) Scott 2895b
Michel 4541 (2006)*



Guyana Scott 3931 Michel BL804 (2006)

5) CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) is a NASA-French (CNES) joint venture that was launched along with CloudSat on 28 April 2006. Similar to CloudSat, CALIPSO's three instruments are only nadir-viewing, with one instrument being an active cloud-aerosol lidar, operating at light wavelengths rather than the radio wavelengths of radar measurements. CALIPSO was placed in the middle of the A-train constellation next to CloudSat. A number of postal items have featured both CloudSat and CALIPSO. (Most of these items are similar in design and were issued by countries having nothing to do with any of these satellites. These items are likely being produced primarily to sell to collectors, while finding limited (if any) postal use.) CALIPSO was moved out of the A-train in September 2018 to CloudSat's new (lower) orbit, to be part of the C-train. A souvenir sheet of one stamp from Guyana nicely depicts CALIPSO with CloudSat in the background, since they have been together in the A-train and later working together in the C-train.

6) OCO (Orbiting Carbon Observatory) is a NASA-sponsored spacecraft, the first of which (OCO-1) was destroyed in a failed launch attempt in 2009. OCO-2 was then rather quickly (in satellite time frames) built as a replacement and was launched in 2014, to become the lead satellite in the A-train constellation. OCO-2 provides global measurements of atmospheric CO₂ that are needed to describe the geographic distribution and variability of CO₂ sources and sinks, to resolve discrepancies in the understanding of the global carbon budget and to better determine the role of humans in global climate change. There is only one postal item showing OCO, issued even before the OCO-1 launch failure. (Similarly, pre-launch status has not prevented other satellites from appearing on stamps before their time in space, or even satellites appearing on stamps which have never been launched. See the 21st article in this un-manned satellite series, for postal items depicting the never-launched AOSO that was to be part of the OSO series.) Again, no separate depictions of OCO-1 or OCO-2 are found on postal items, only as part of one of the items depicting the A-train to be shown later.

7) Another satellite, **Glory** would have flown between CALIPSO and EOS-Aura, to be another satellite in the A-train. But, Glory suffered from a launch failure in 2011. It therefore was never part of the A-train and was never replaced like OCO-2 replaced OCO-1. Glory was to be an Earth science mission, with an instrument to measure atmospheric aerosols and a Total Irradiance Monitor to continue the mission of **SORCE** (Solar Radiation and Climate Experiment) which was launched in 2003 but is not part of the A-train. Another instrument was to measure the levels of man-made pollutants in the atmosphere. No postal items are known to show Glory, but a few launch covers exist for its failed launch.

8) **GCOM-W (Global Change Observation Mission - Water [Shizuku])** is a Japanese climate satellite launched in 2012, to become the second satellite in the A-train. (A similar **GCOM-C [Climate change] / Shikisai** satellite launched in 2017 is not part of the A-train.) **GCOM-W** was designed for continuous global-scale observations (for 10 to 15 years) of effective geophysical parameters for global climate change and water circulation mechanisms. **GCOM-W** observes precipitation, water vapor amounts, wind velocity above the ocean, sea water temperatures, water levels on land areas, and snow depths. No postal items or launch covers have been found showing **GCOM-W**.

Summary table of A-train satellite count

With satellites being launched and moving into the A-train and other satellites moving out of the A-train, a summary table of those satellite events is provided below. As many as 8 satellites were potentially part of the A-train, not considering the OCO-2 replacement for OCO-1. But only 7 of those were ever part of the A-train, since Glory suffered a launch failure and was never replaced. Of the rest, there were a maximum of 6 satellites in the A-train from about 2014 to 2018. Below is a simplified list of satellite events and a count of the number of satellites in the A-train over time. The count goes up for satellites launches, stays the same for satellite launch failures, and goes down when satellites move out of the A-train.

Postal items showing the A-train constellation

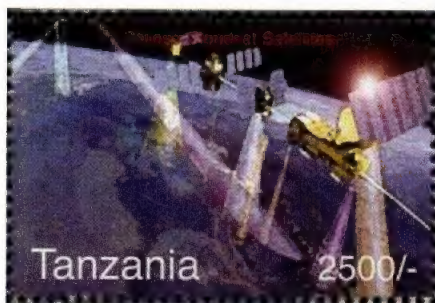
Readers are encouraged to check the authors' website for all known postal items of the satellites that are or were part of the A-train constellation. Otherwise, two more postage stamps will accompany this article, the only two that are known to show the A-train constellation at different stages in its evolution. The first stamp issued by Sierra Leone in 2006 shows a 6-satellite A-train constellation in which OCO-1 is depicted, but it was not yet launched and even then was not replaced by OCO-2 until 2014.

Date	Satellite Event	Number of satellites in A-train
2002-05-04	EOS-Aqua launch	1
2004-07-15	EOS-Aura launch	2
2004-12-18	PARASOL launch	3
2006-04-28	CloudSat and CALIPSO launch	5
2009-02-24	OCO-1 launch failure	5
2009-12-02	PARASOL moved to lower orbit	4
2011-03-04	Glory launch failure	4 -
2012-05-17	GCOM-W launch	5
2014-07-02	OCO-2 launch	6
2018-02-22	CloudSat moved to C-train	5
2018-09-18	CALIPSO moved to C-train	4



Sierra Leone Scott 2871d Michel 4976 (2006) [only one stamp from a souvenir sheet of four is shown] [left to right: EOS-Aura, PARASOL, CALPSO, CloudSat, EOS-Aqua, and OCO]

A second stamp issued by Tanzania in 2008 shows a 5-satellite A-train constellation, the most common configuration for several years during the early A-train. The only difference from the first stamp is that OCO-1 is not depicted, but as already mentioned OCO-2 was not launched as a replacement and did not become part of the A-train until many years later.



Tanzania Scott 2444 Michel BL592 (2008) [only the stamp from a souvenir sheet of one is shown][left to right: EOS-Aura (just off top edge of stamp), PARASOL, CALIPSO, CloudSat, and EOS-Aqua]

Readers are encouraged to examine the authors' A-train postal items and provide information about any postal items that may have been missed. For postal items showing the A-train constellation satellites see (<https://rammb.cira.colostate.edu/dev/hillger/a-train.htm>), which is part of the website developed by the authors for the un-manned satellites (<https://rammb.cira.colostate.edu/dev/hillger/satellites.htm>). E-mail correspondence with the authors is welcome. Don Hillger can be reached at don.hillger@colostate.edu and Garry Toth at gmt.varia@gmail.com.